Jet Propulsion Laboratory
California Institute of Technology

# Impacts of Radiative Effects of Precipitating Ice on Central-Pacific Seasonal and El Nino Simulations in Contemporary GCMs


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and

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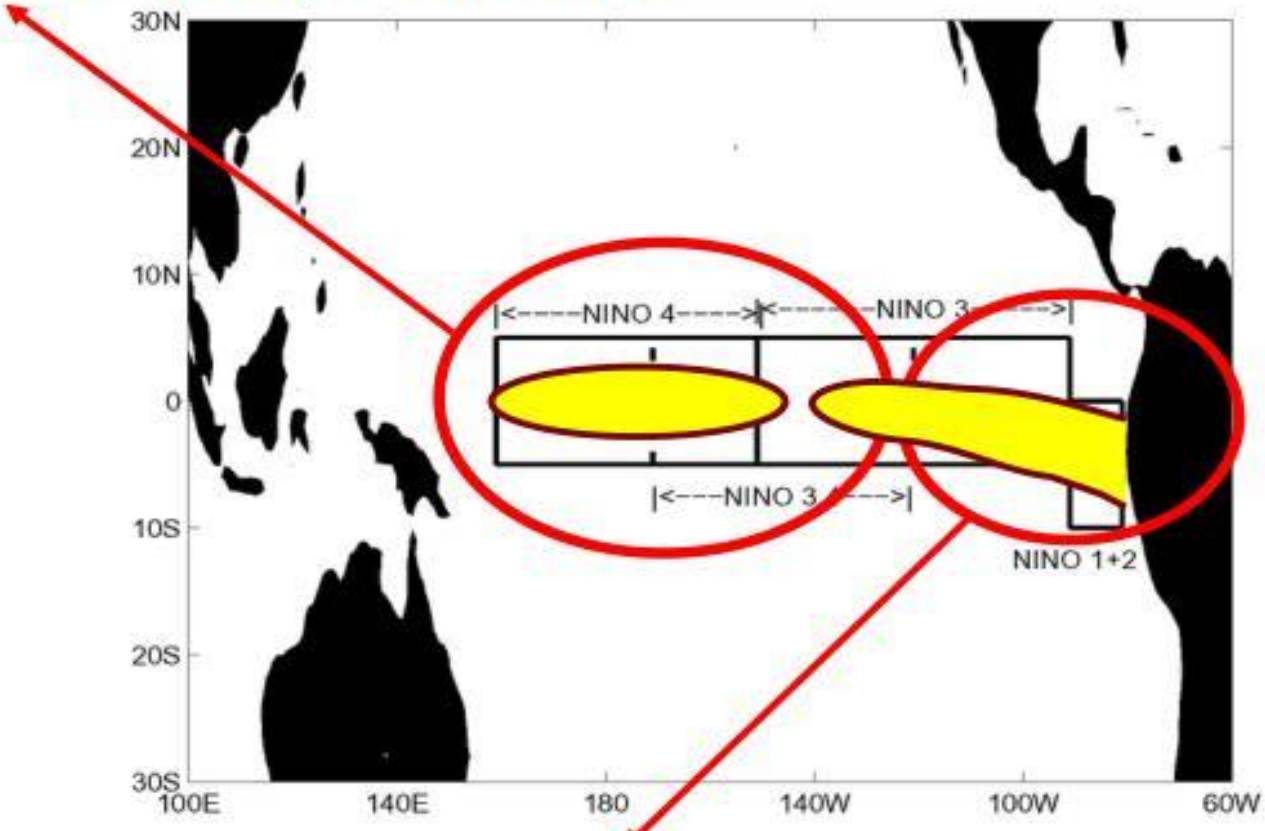
# The Two Types of ENSO

(Yu and Kao 2007; Kao and Yu 2009)

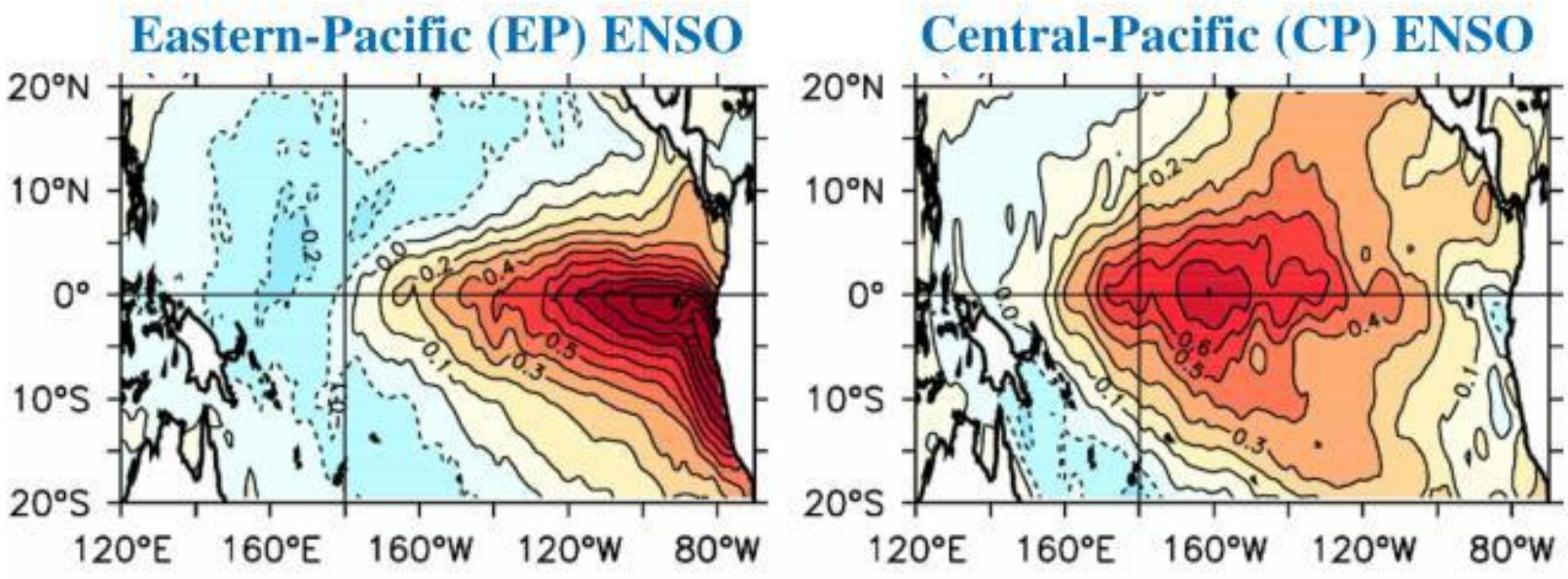
## Central-Pacific El Niño




## Eastern-Pacific El Niño

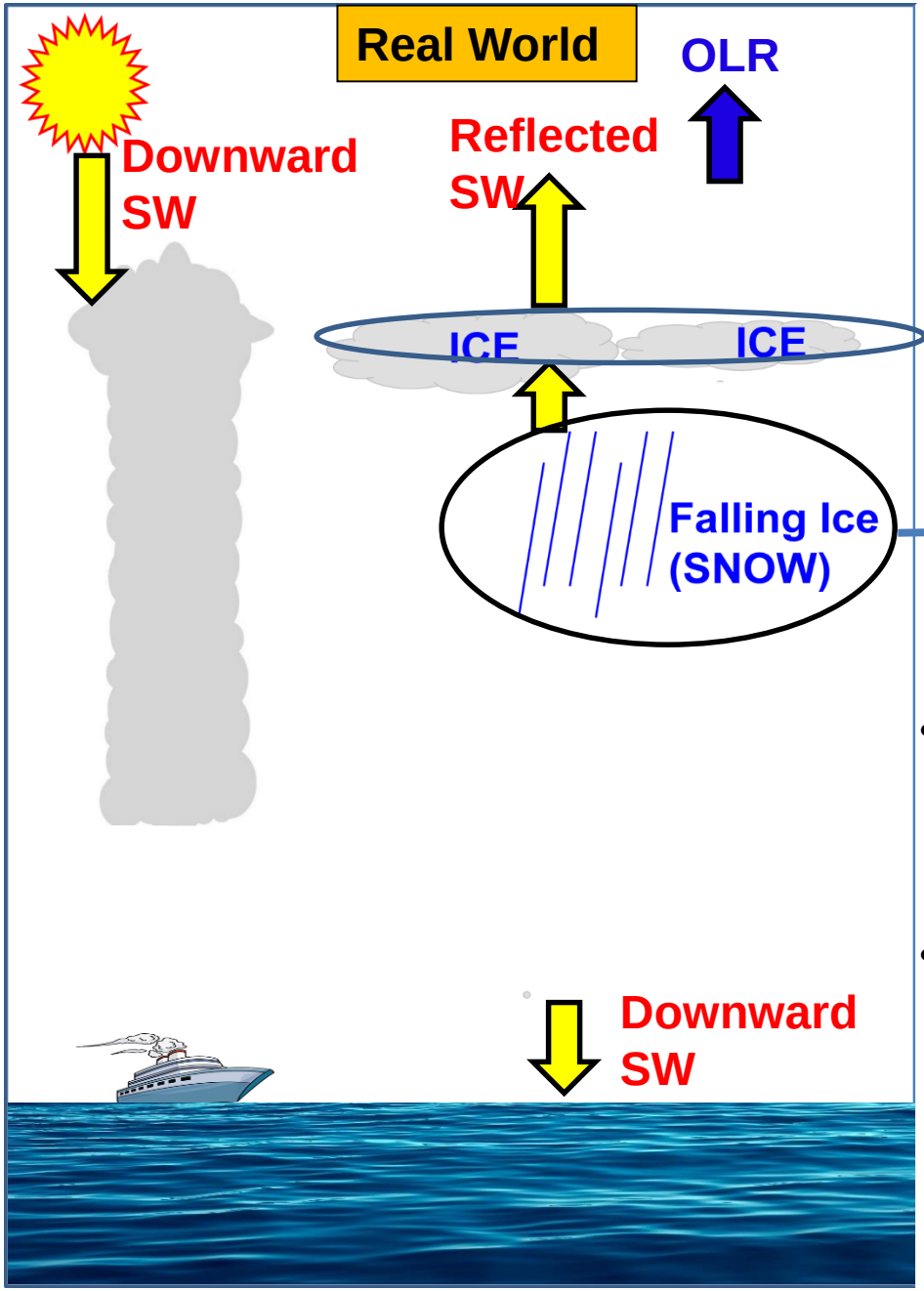
# Regression-EOF Method for EP/CP-ENSO

(Kao and Yu 2009)




Courtesy of Prof. Jin-Yi Yu

# Falling Ice (Snow) Radiation Effects over ITCZ, SPCZ and Warm Pool



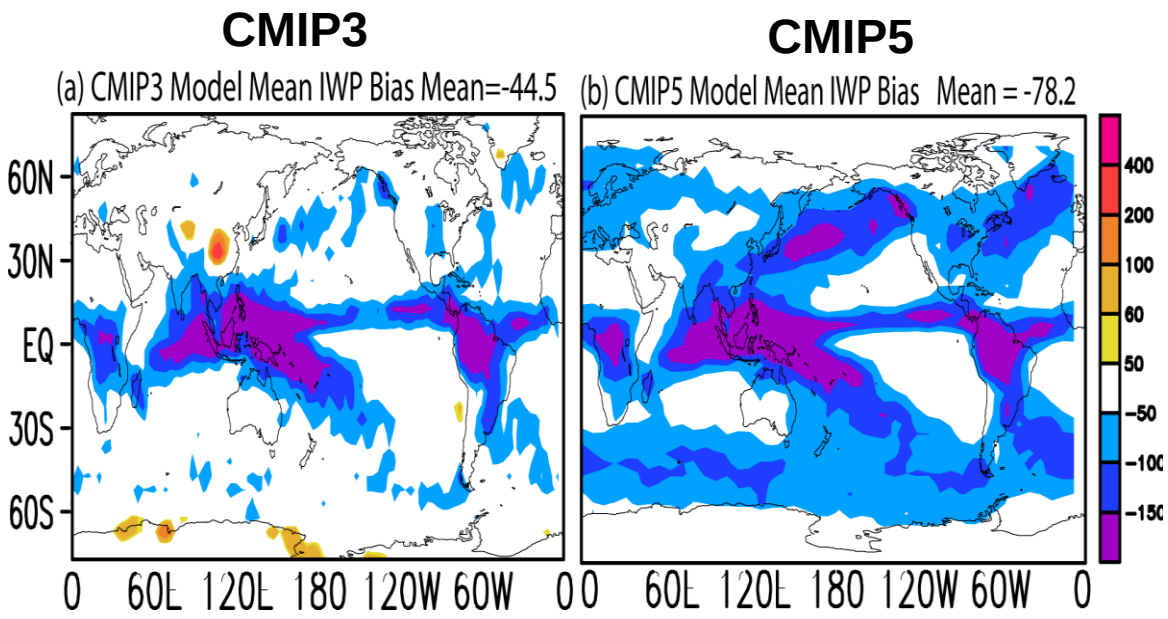

**CloudSat + CALIPSO Measurements are sensitive to:**

**Floating ice**

**Falling ice**

- **All CMIP3 and most CMIP5 GCMs do not consider falling ice radiative effects.**
- **Few GCMs in CMIP5 such as NASA-GISS model, NCAR-CAM5, GFDL-AM3 and CSIRO etc include falling ice radiative effects**

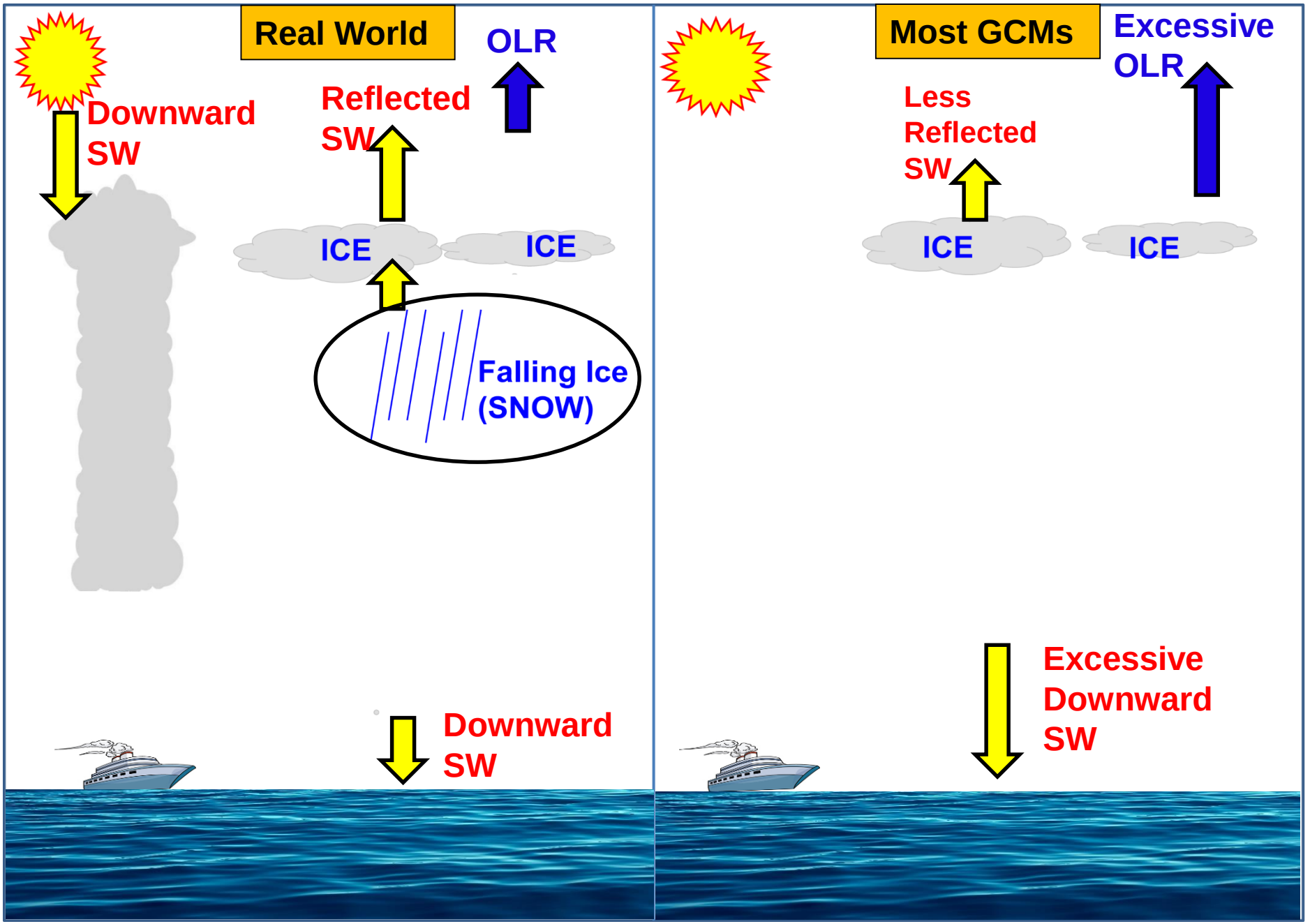
# Bias of CMIP3, CMIP5 and CMIP6 (four) Ensemble Mean CIWP vs Obs. *Total CloudSat+CALIPSO ice water path (*IWP)



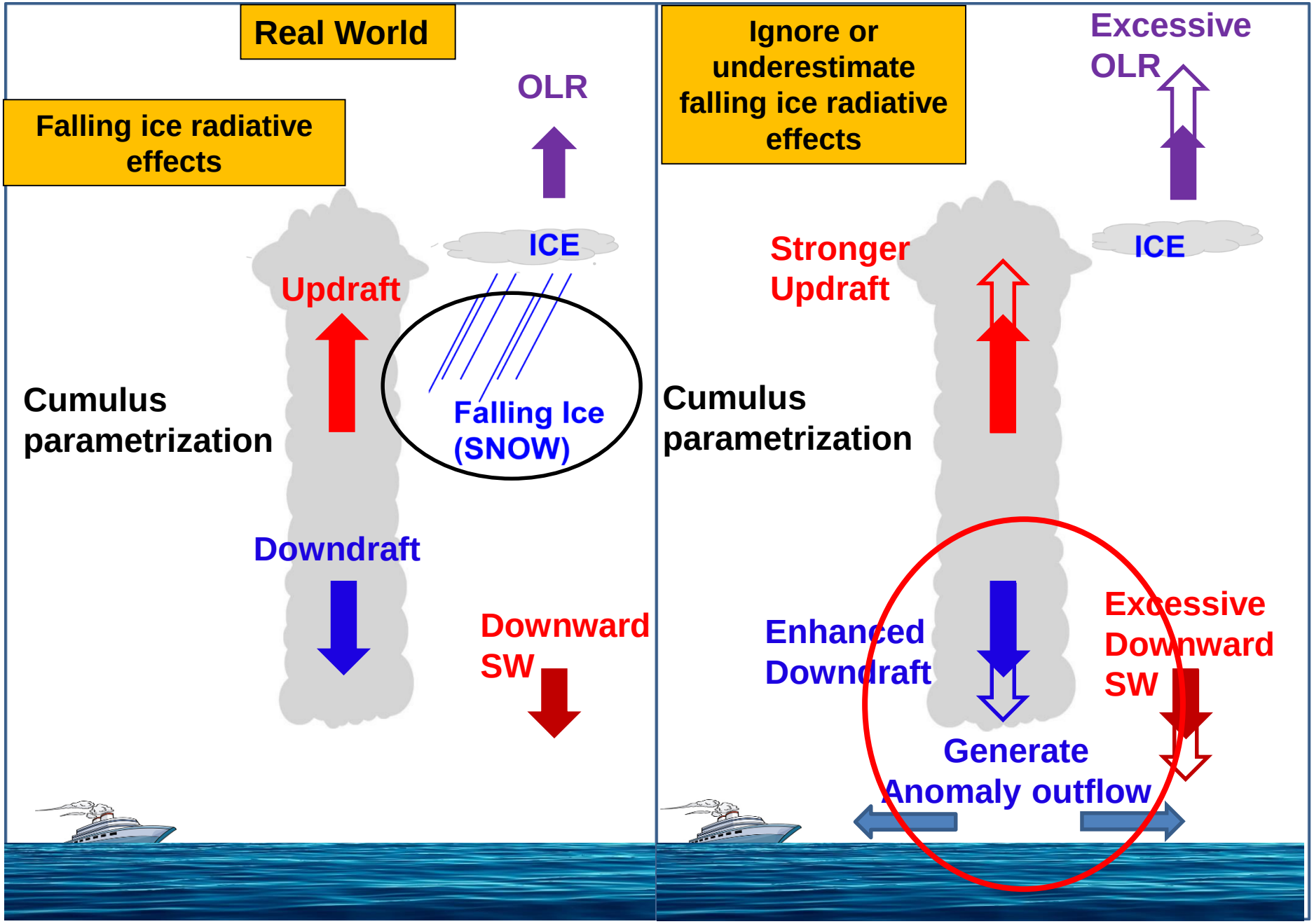

## Underestimated Total cloud IWP

Li, J.-L. F., D. E. Waliser, W.-T. Chen, B. Guan, T. Kubar, G. Stephens, H-Y Ma, D. Ming, L. Donner, C. Seman, and L. Horowitz, (2012), An observationally based evaluation of cloud ice water in CMIP3 and CMIP5 GCMs and contemporary reanalyses using contemporary satellite data, J. Geophys. Res., doi:10.1029/2012JD017640.

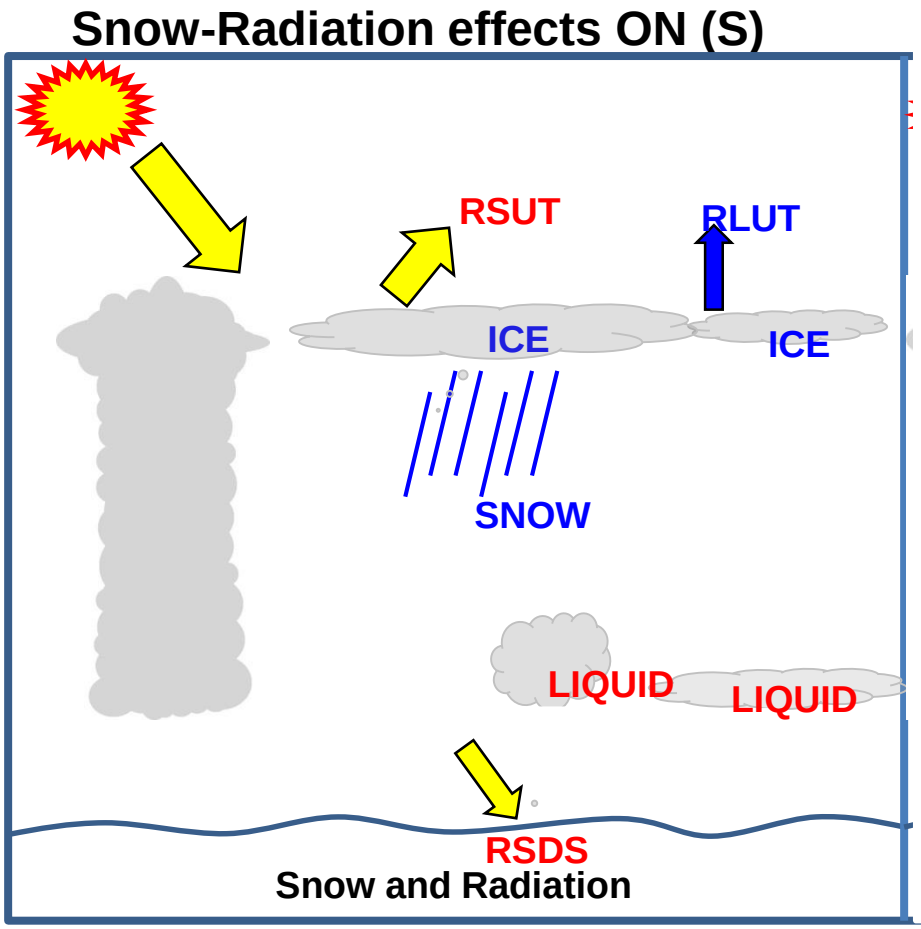
# Falling Ice (Snow) Radiation Effects over ITCZ, SPCZ and Warm Pool



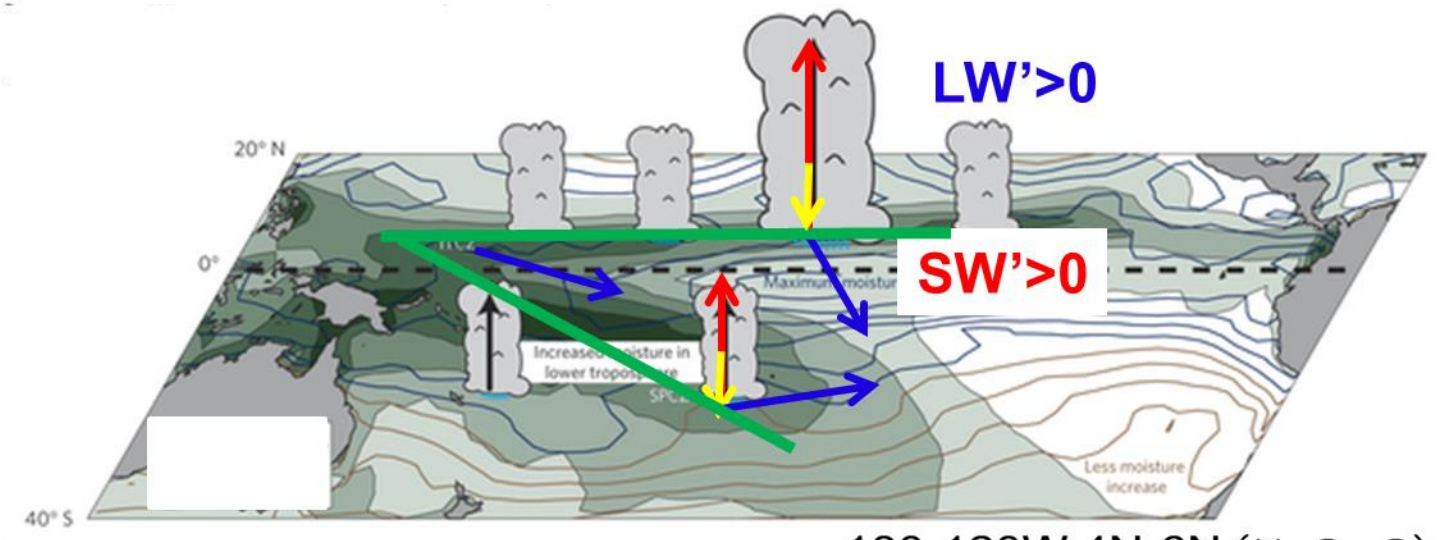
# Precipitating Ice Radiative Effects in Cumulus Scheme in GCMs

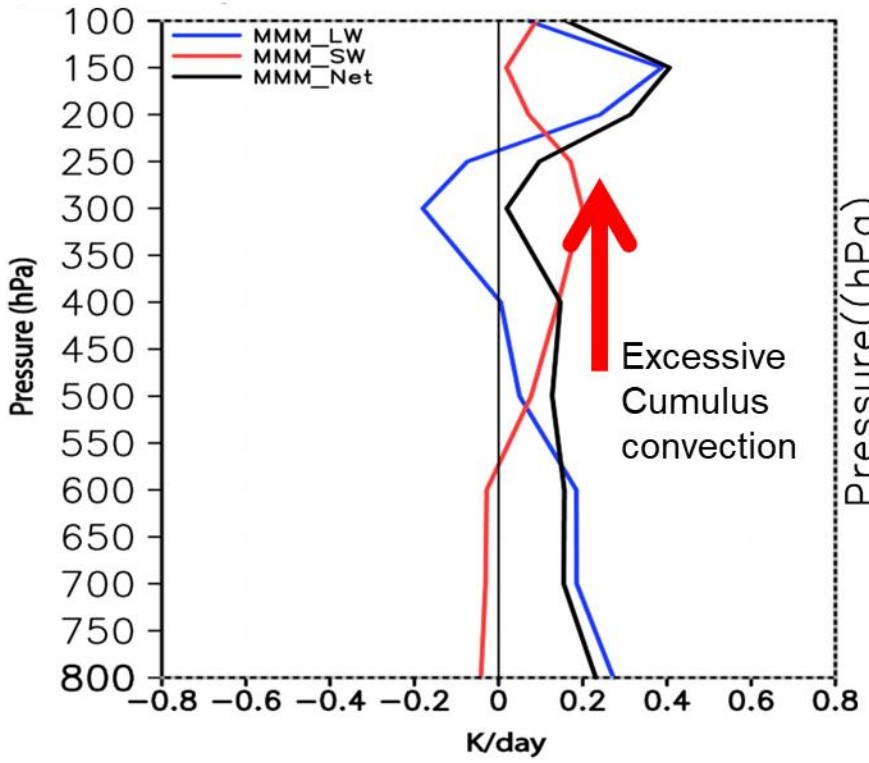


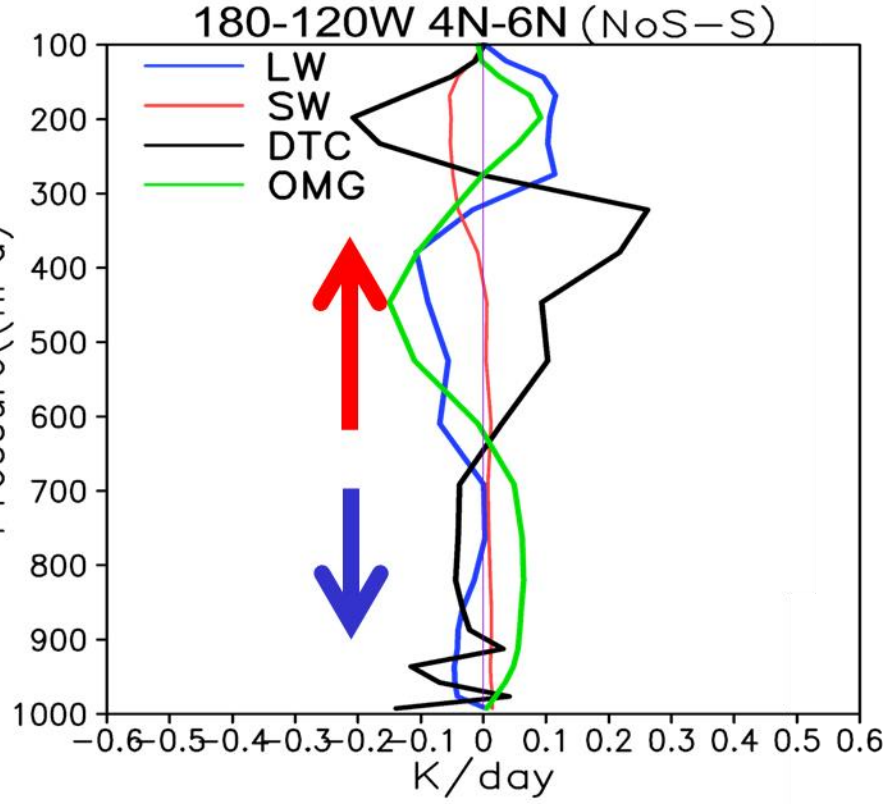
# NCAR CESM1-CAM5 Snow-Radiation Effects Sensitivity Tests




- **NCAR CESM1-CAM5: Exclusion of radiative diagnostic snow**
  - **CESM1-CAM5-POP2: CMIP5 Historical Configuration (140 Years)**
    - **NoS = snow-radiation interaction OFF**
    - **S = snow-radiation ON**

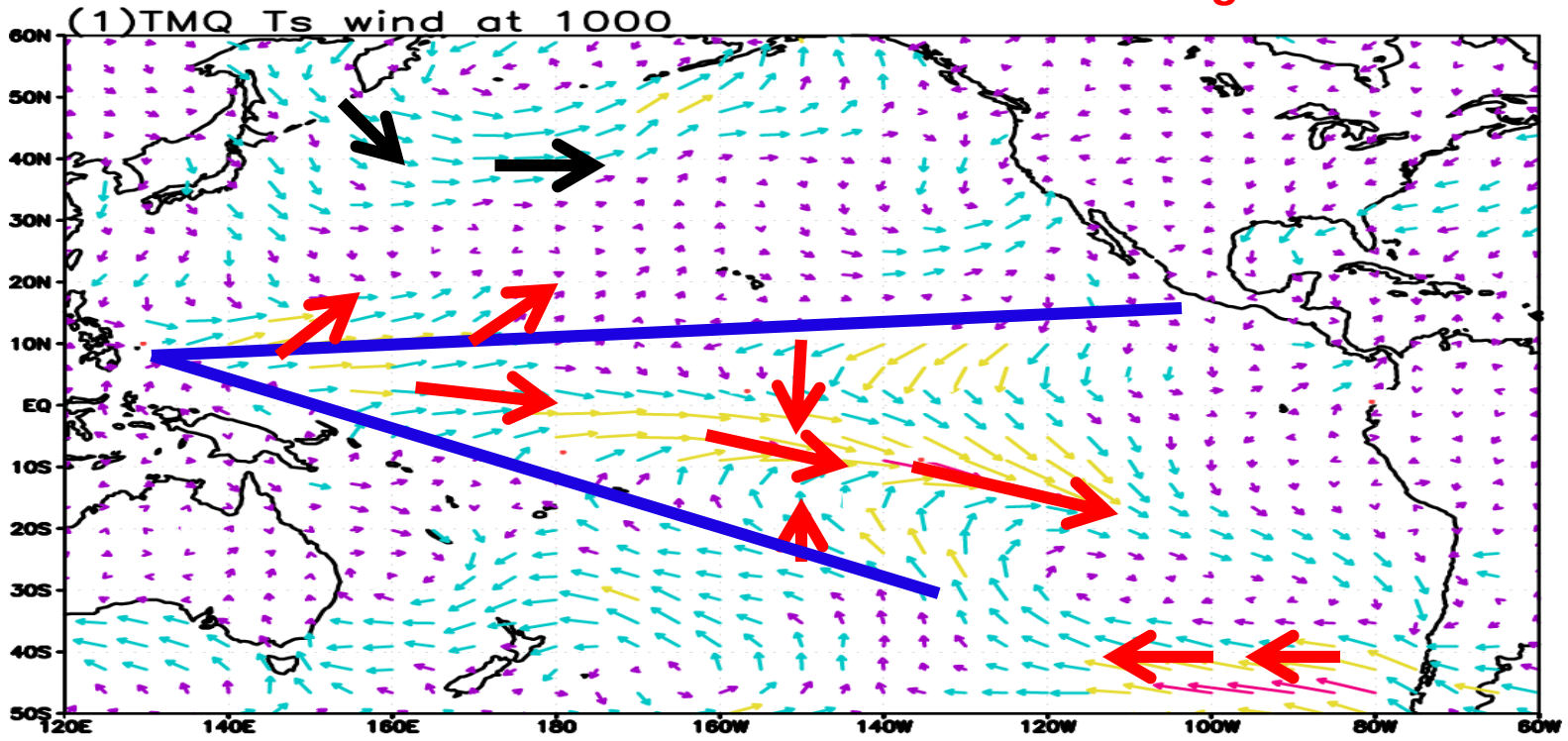

LW'>0
SW'>0
20° N
0°
40° S
Less moisture increase


MMM_LW
MMM_SW
MMM_Net
Pressure (hPa)
K/day
Excessive Cumulus convection

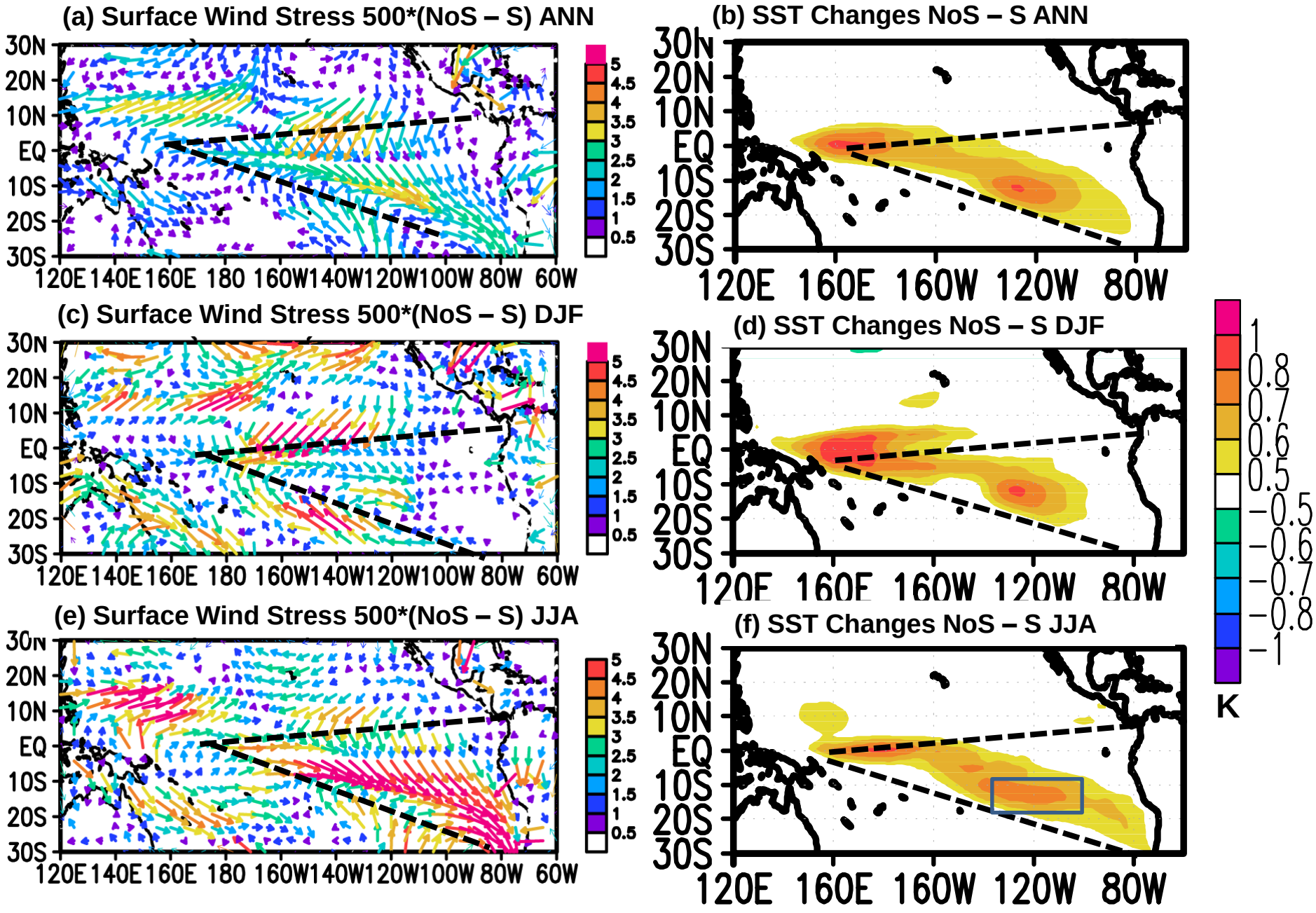

180-120W 4N-6N (NoS−S)
LW
SW
DTC
OMG
Pressure((hPa)
K/day

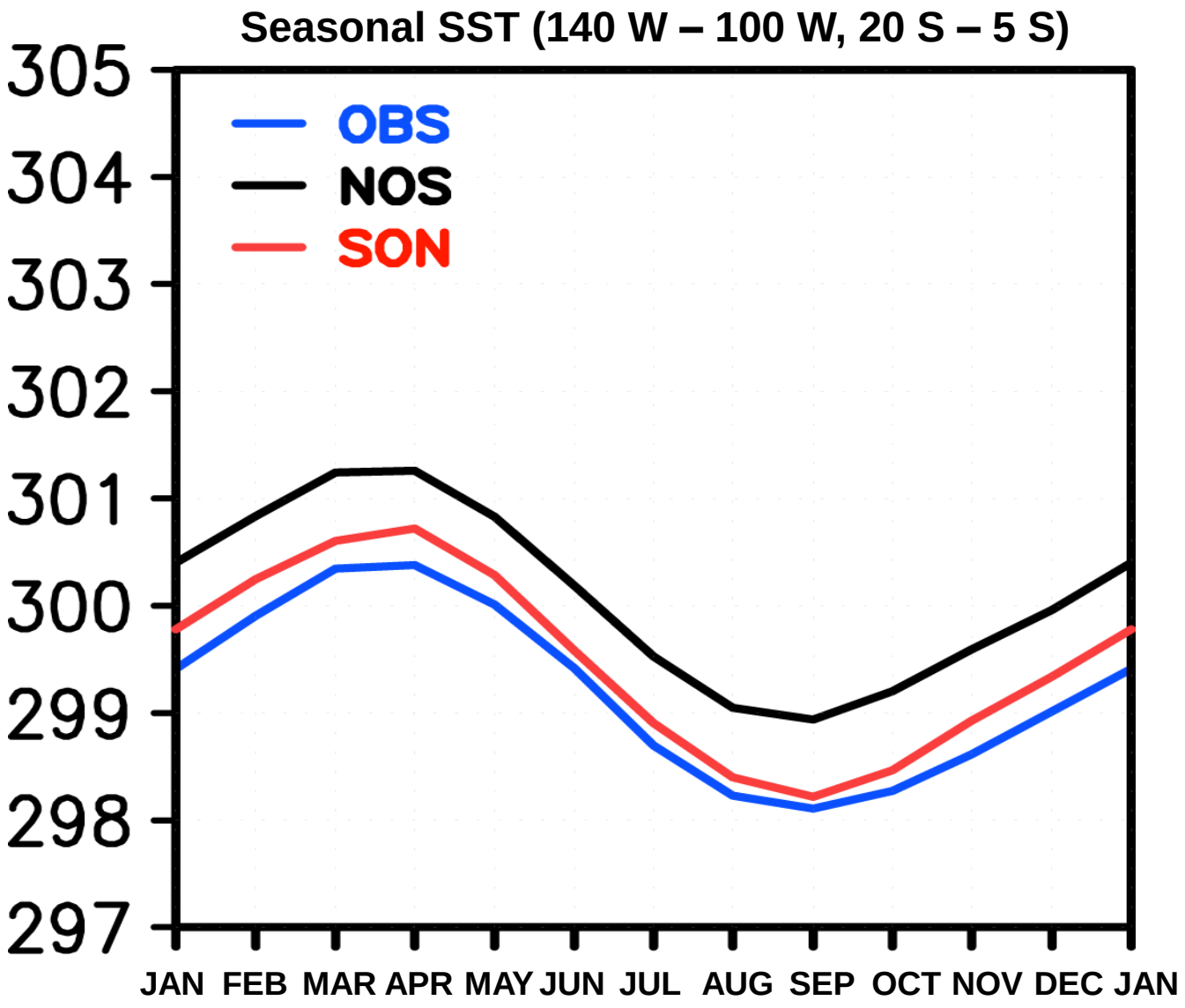
# The IMPACTS of Exclusion of Snow-Radiative Effects

## Model Ocean Surface Wind Vector Changes



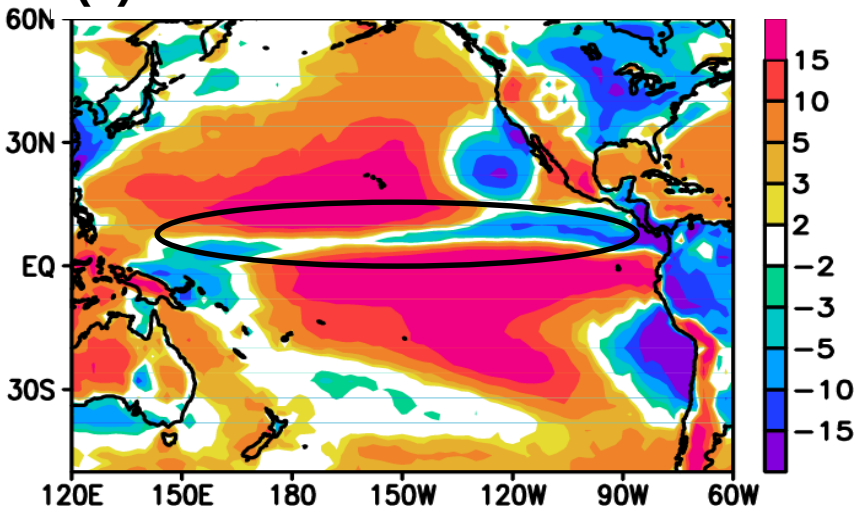

**Weaker surface wind stress and trade-winds**


(a) Surface Wind Stress 500*(NoS – S) ANN
(b) SST Changes NoS – S ANN
(c) Surface Wind Stress 500*(NoS – S) DJF
(d) SST Changes NoS – S DJF
(e) Surface Wind Stress 500*(NoS – S) JJA
(f) SST Changes NoS – S JJA
30N
20N
10N
EQ
10S
20S
30S
120E 140E 160E 180 160W 140W 120W 100W 80W 60W
120E 160E 160W 120W 80W
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
1
0.8
0.7
0.6
0.5
−0.5
−0.6
−0.7
−0.8
−1
K

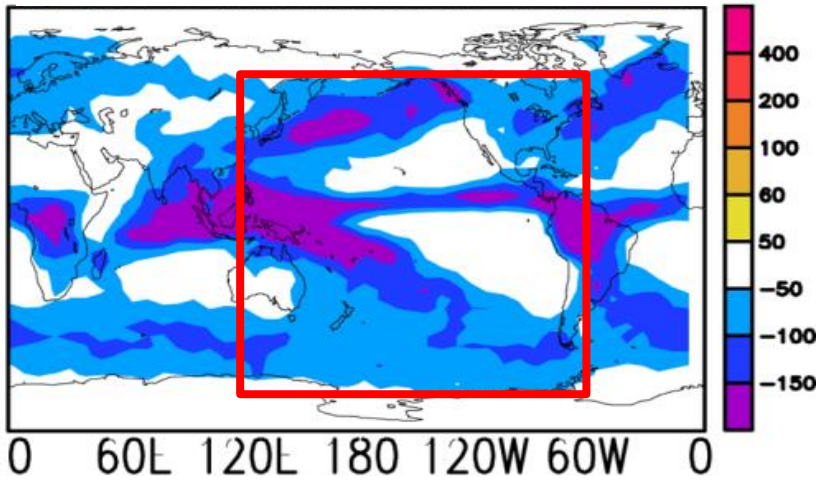

Seasonal SST (140 W – 100 W, 20 S – 5 S)
305
304
303
302
301
300
299
298
297
OBS
NOS
SON
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN

# Bias of CMIP5 Ensemble Mean Radiation

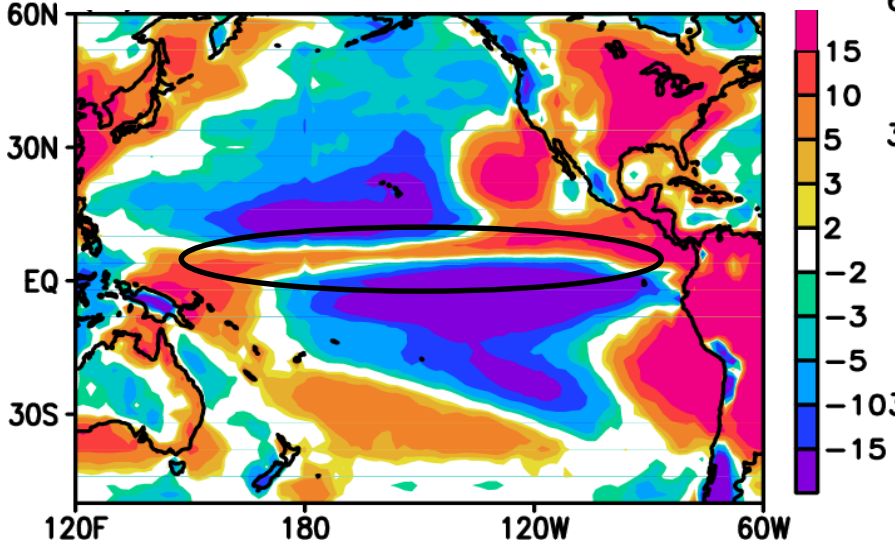
## (a) Reflected Shortwave at TOA



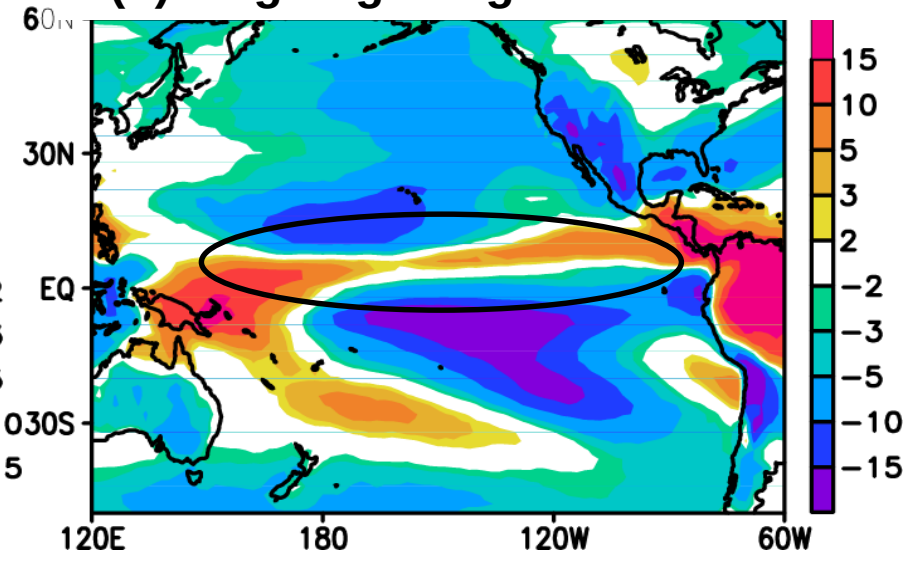

## (b) CMIP5 IWP minus Obs.



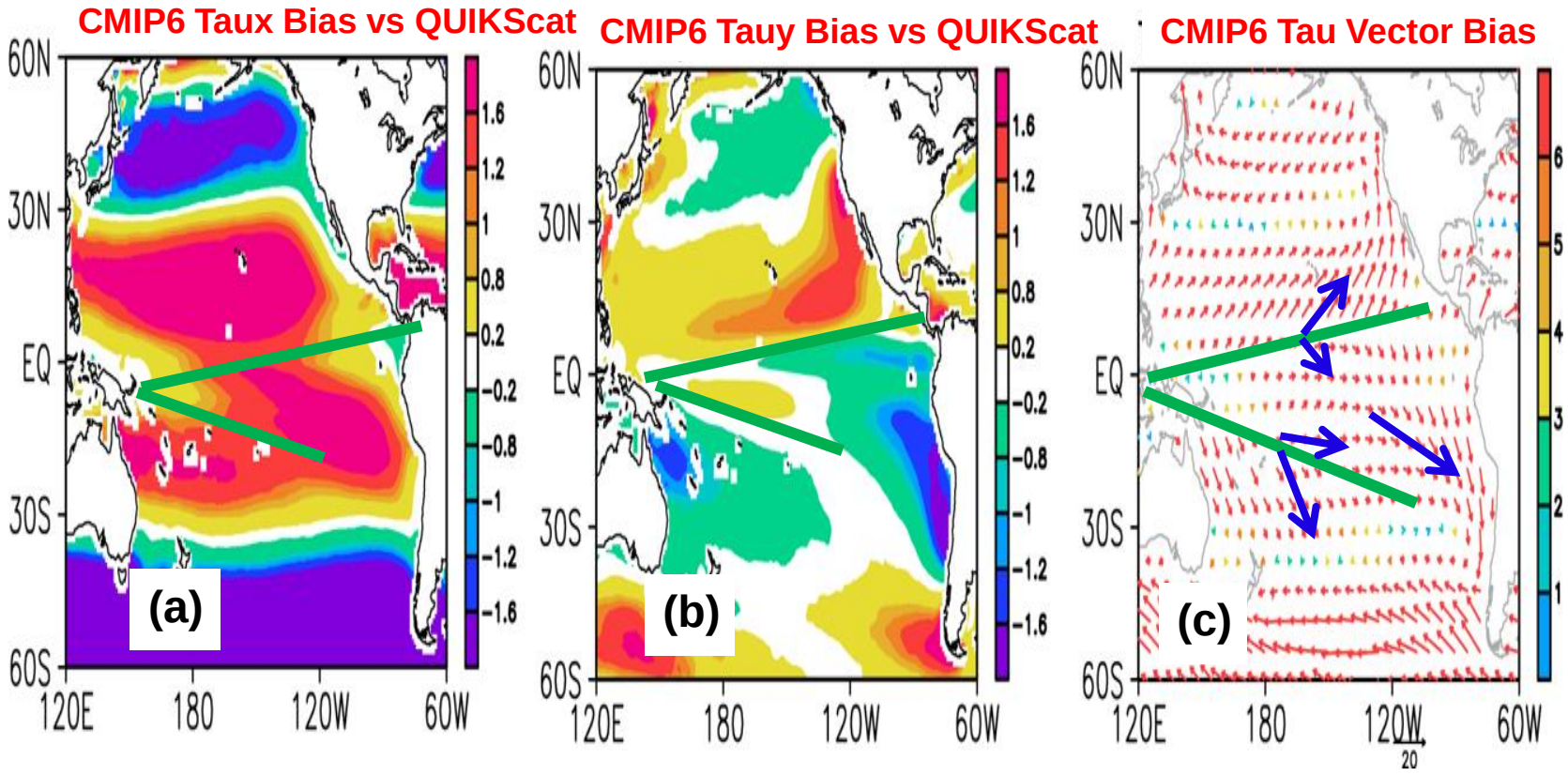

## (c)Downward Shortwave at SFC




## (d)Outgoing Longwave at TOA

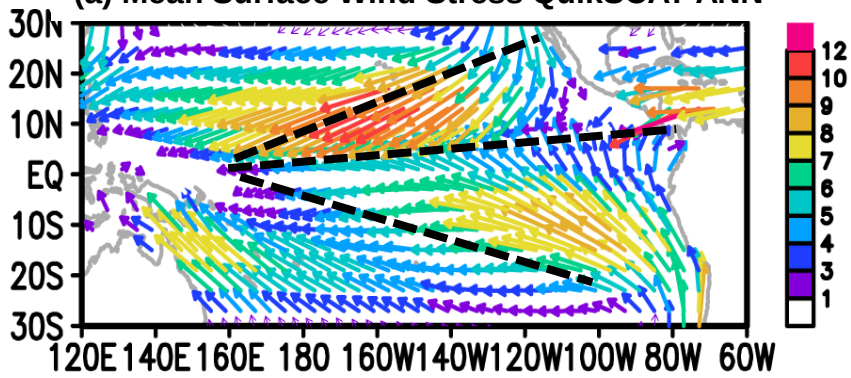


# CMIP6 Surface Wind Stress BIAS

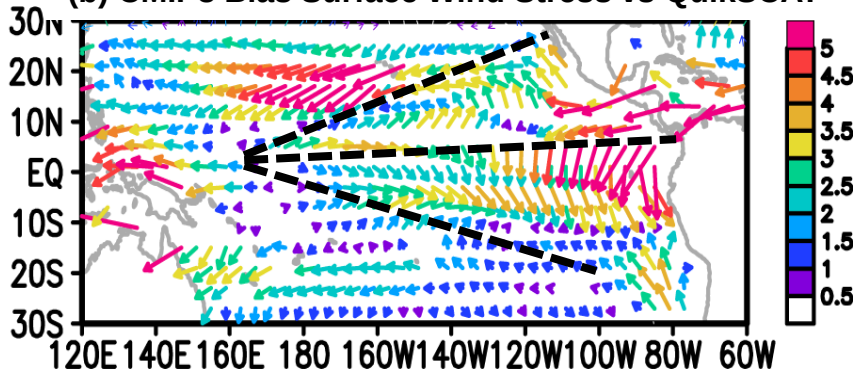



***The CMIP6 bias of annual mean maps of: (a) east-west surface wind stress magnitudes against QUIKSCAT; (b) same as in (a) but for north-south surface wind magnitudes (Wind; m $s^{-1}$); (c) same as in (a) but for the surface wind stress vectors from the 20$^{th}$ century (1970–2005) simulations from the CMIP6 historical run.***

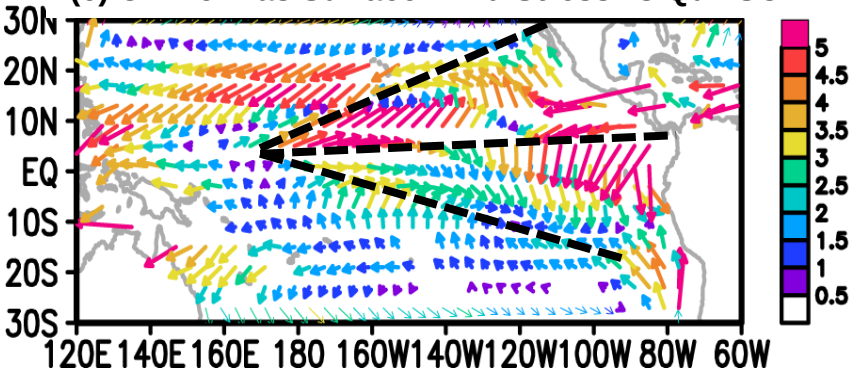
(a) Mean Surface Wind Stress QuikSCAT ANN



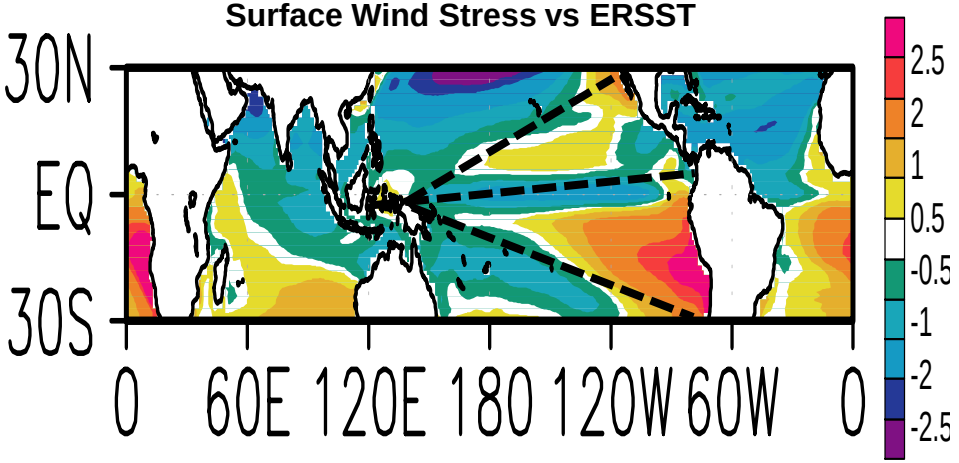

(b) CMIP3 Bias Surface Wind Stress vs QuikSCAT

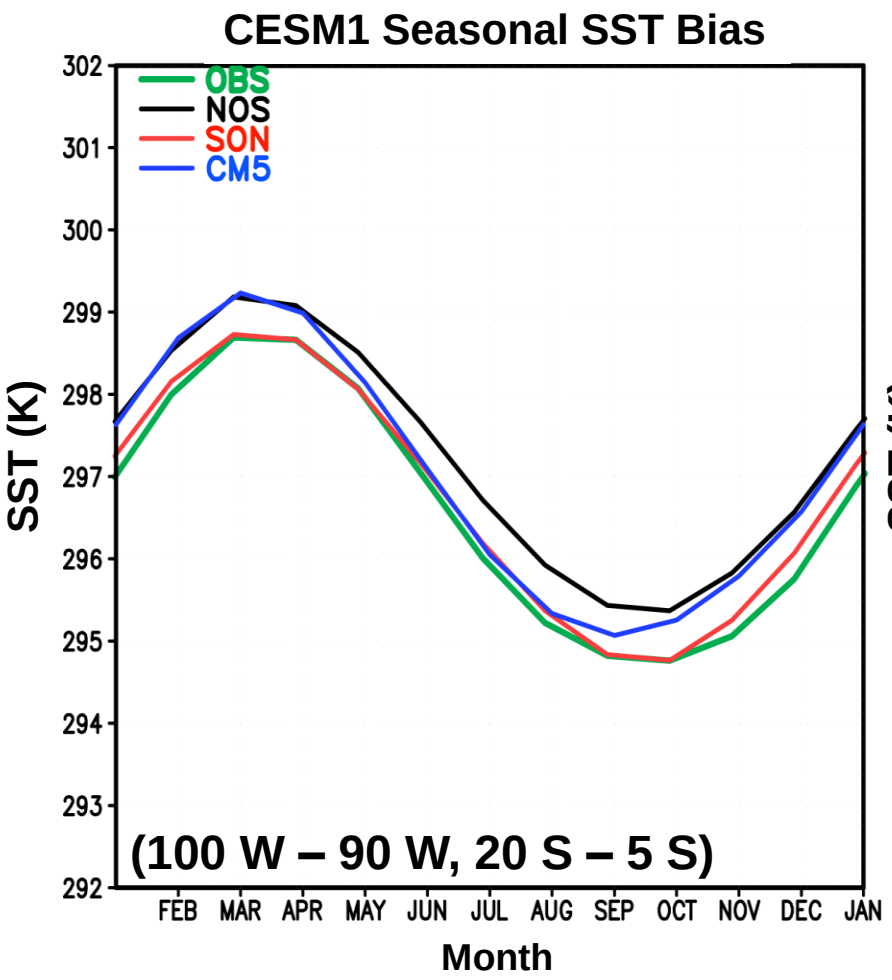


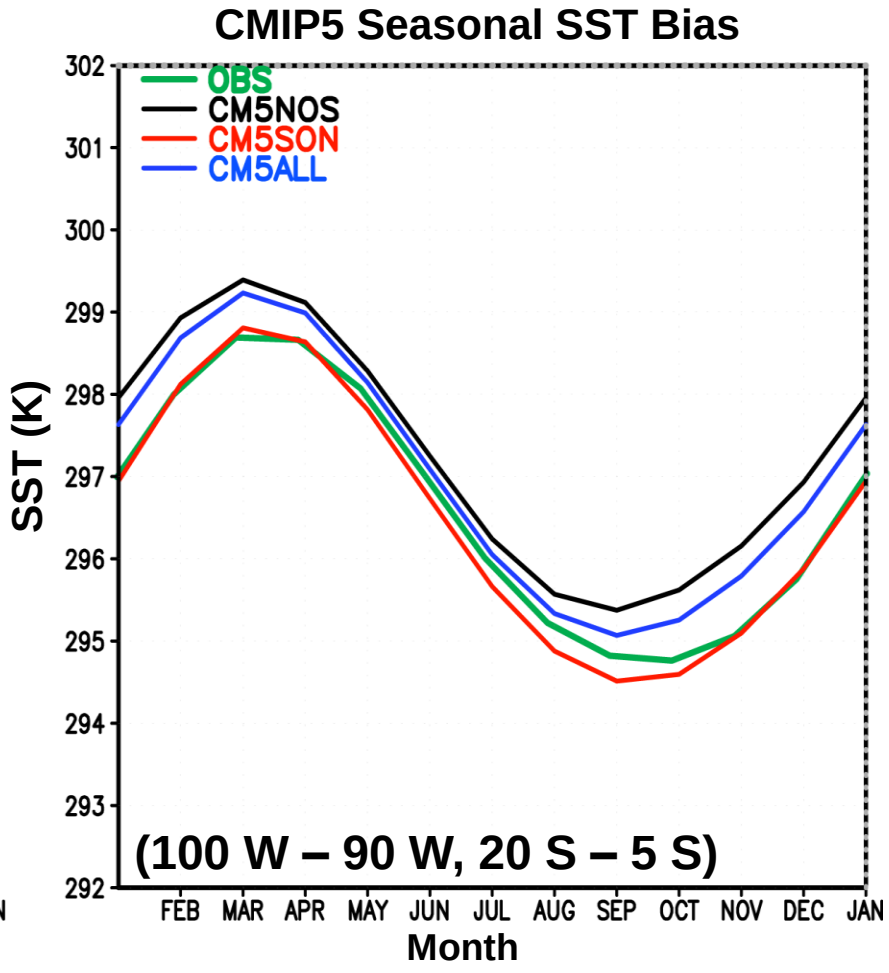

(c) CMIP5 Bias Surface Wind Stress vs QuikSCAT

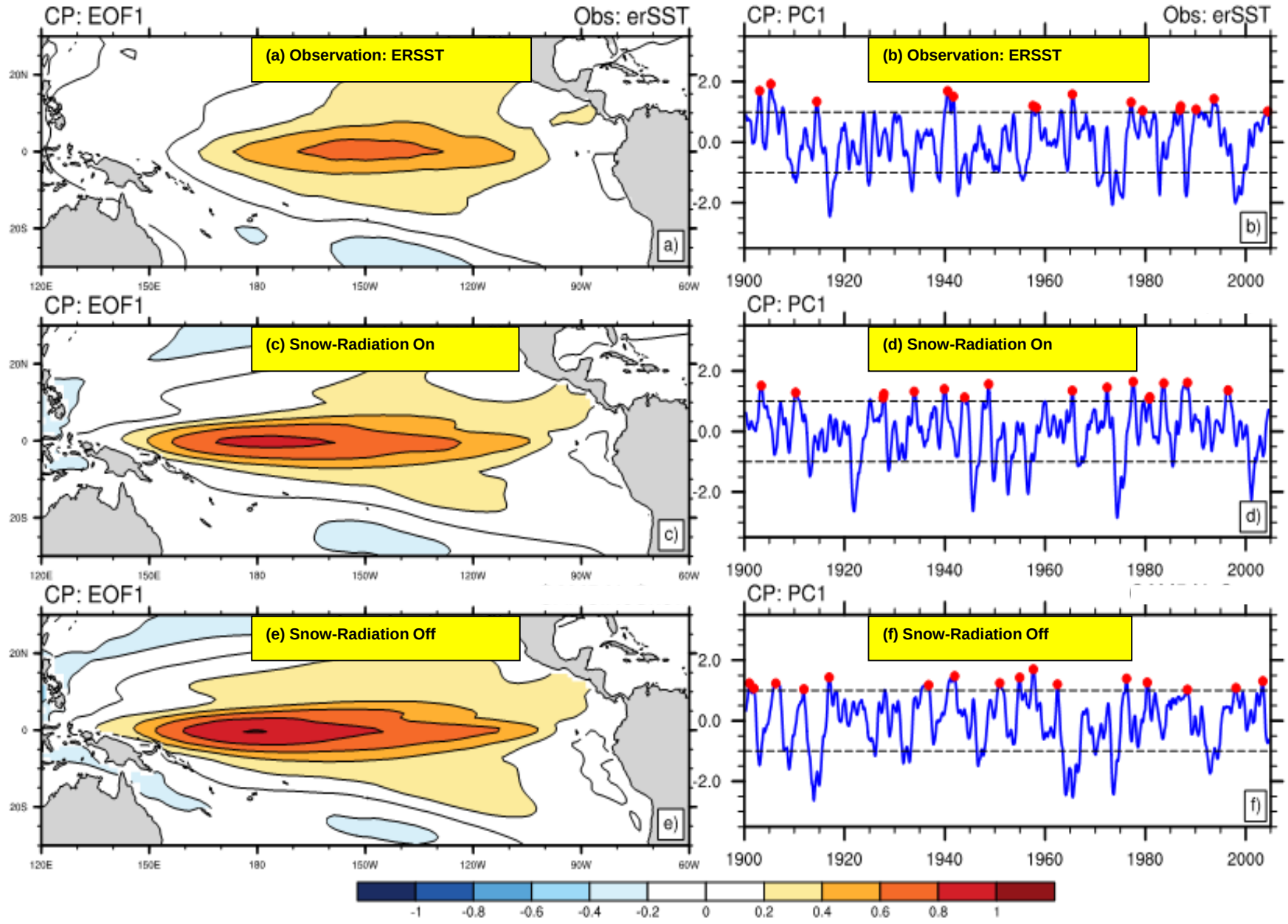



(d) CMIP5 Bias Sea Surface Temperatures
Surface Wind Stress vs ERSST

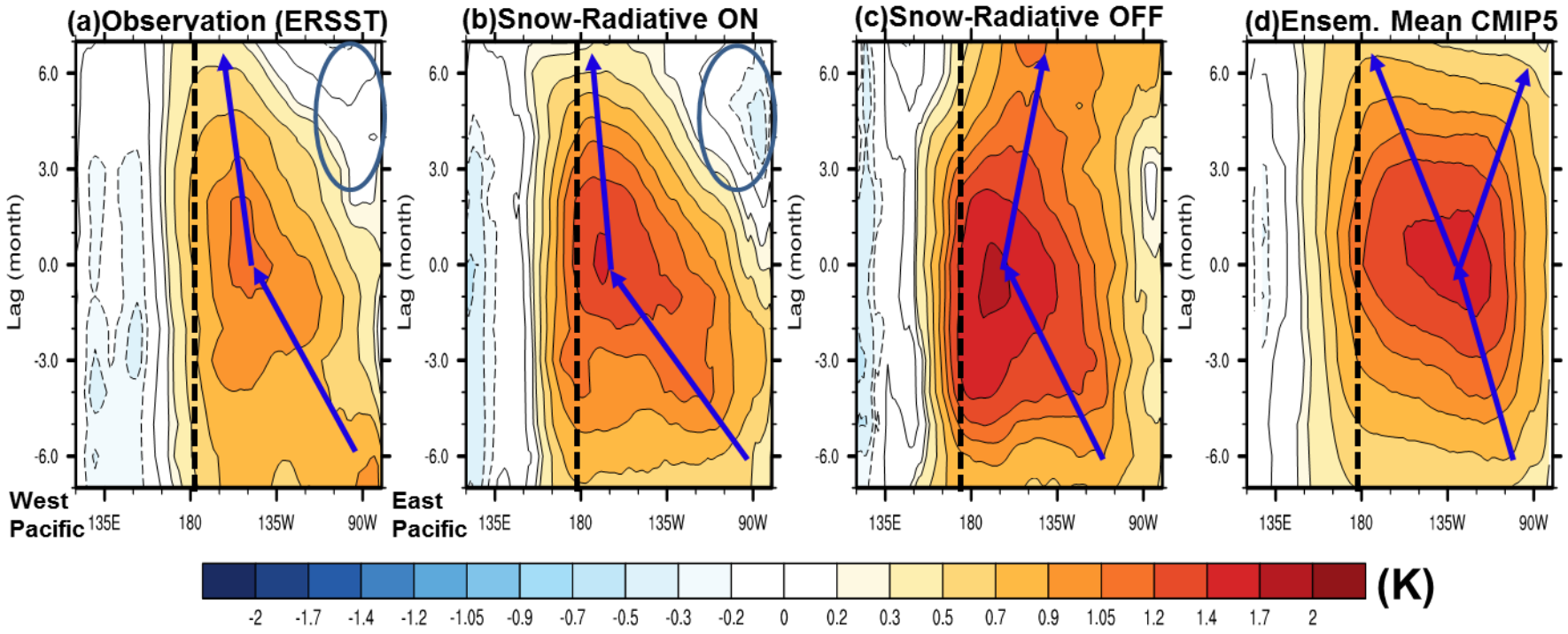


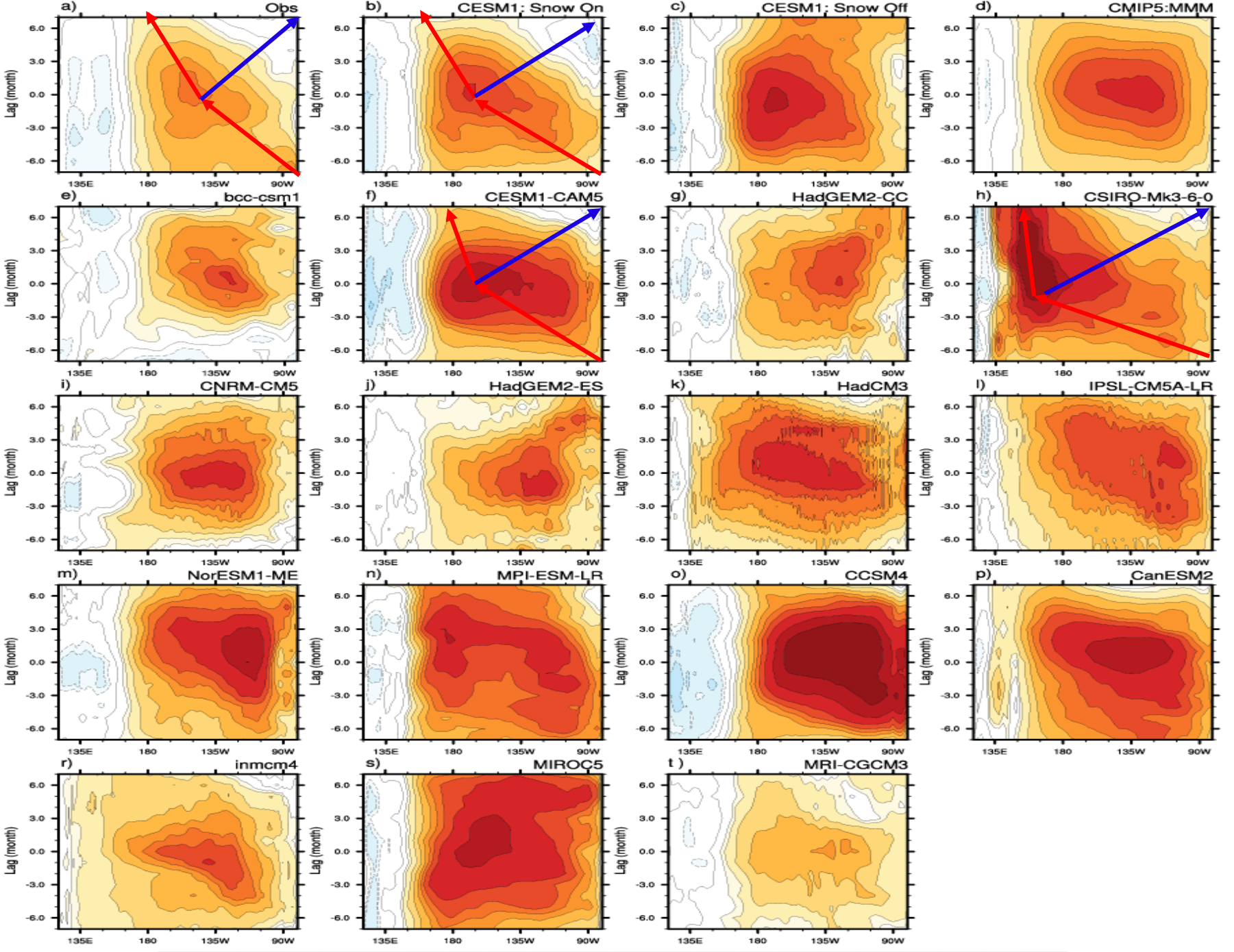

CESM1 Seasonal SST Bias
OBS
NOS
SON
CM5
SST (K)
302
301
300
299
298
297
296
295
294
293
292
(100 W – 90 W, 20 S – 5 S)
FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN
Month

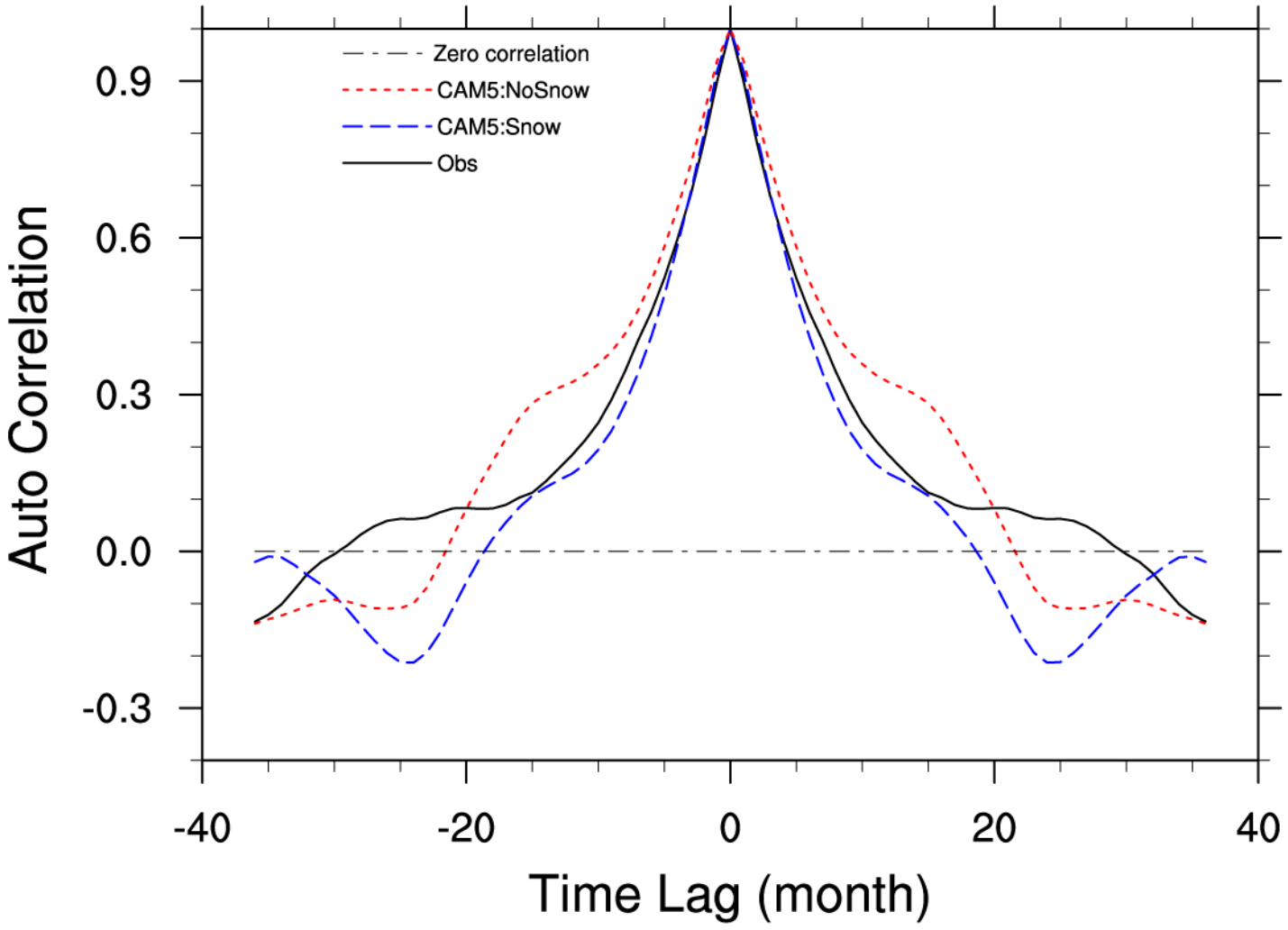

CMIP5 Seasonal SST Bias
OBS
CM5NOS
CM5SON
CM5ALL
SST (K)
302
301
300
299
298
297
296
295
294
293
292
(100 W – 90 W, 20 S – 5 S)
FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN
Month


CP: EOF1
Obs: erSST
(a) Observation: ERSST
CP: PC1
Obs: erSST
(b) Observation: ERSST
CP: EOF1
(c) Snow-Radiation On
CP: PC1
(d) Snow-Radiation On
CP: EOF1
(e) Snow-Radiation Off
CP: PC1
(f) Snow-Radiation Off
20N
0
20S
120E
150E
180
150W
120W
90W
60W
2.0
0.0
-2.0
1900
1920
1940
1960
1980
2000
a)
b)
c)
d)
e)
f)
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1

# Central Pacific ENSO Cycle (1900~2005) SST Anomaly Observations and Modeling




a) Obs
b) CESM1; Snow On
c) CESM1; Snow Off
d) CMIP5:MMM
e) bcc-csm1
f) CESM1-CAM5
g) HadGEM2-CC
h) CSIRO-Mk3-6-0
i) CNRM-CM5
j) HadGEM2-ES
k) HadCM3
l) IPSL-CM5A-LR
m) NorESM1-ME
n) MPI-ESM-LR
o) CCSM4
p) CanESM2
r) inmcm4
s) MIROC5
t ) MRI-CGCM3
Lag (month)
6.0
3.0
0.0
-3.0
-6.0
135E
180
135W
90W
-2 -1.7 -1.4 -1.2 -1.05 -0.9 -0.7 -0.5 -0.3 -0.2 0 0.2 0.3 0.5 0.7 0.9 1.05 1.2 1.4 1.7 2


Zero correlation
CAM5:NoSnow
CAM5:Snow
Obs
Auto Correlation
0.9
0.6
0.3
0.0
-0.3
-40
-20
0
20
40
Time Lag (month)

# Summary and Conclusion

- **Current GCMs exclude snow-radiative effects**
- **Excluding snow-radiative effects leads to weakening surface wind stress and warming SSTs in seasonal variation and CP-El Nino**
- **Including snow-radiative effects largely reduces the model biases of CP-El Nino events**
- **Inclusion of the contribution of the snow and its radiative effects in models is important to improve the simulation of the Pacific mean state, seasonal cycle, and CP-El Niño**